



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup>:</b> <b>E21B 43/38</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 95/09970</b> <b>(43) International Publication Date:</b> 13 April 1995 (13.04.95)
<b>(21) International Application Number:</b> PCT/NO94/00159 <b>(22) International Filing Date:</b> 30 September 1994 (30.09.94)  <b>(30) Priority Data:</b> 933517                      1 October 1993 (01.10.93)                      NO  <b>(71) Applicant (for all designated States except US):</b> ANIL A/S [NO/NO]; Ravnsborgveien 56, N-1364 Hvalstad (NO).  <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> KJOS, Tore [NO/NO]; Holsteinveien 3, N-0874 Oslo (NO).  <b>(74) Agent:</b> REISTAD, Gunnar, O.; Bryns Patentkontor A/S, P.O. Box 765, Sentrum, N-0106 Oslo (NO).		<b>(81) Designated States:</b> AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).  <b>Published</b> <i>With international search report.</i> <i>In English translation (filed in Norwegian).</i>
<b>(54) Title:</b> METHOD AND APPARATUS FOR SEPARATING A WELL STREAM		
<b>(57) Abstract</b> <p>A process and process equipment are described for gas separation (H<sub>2</sub>S - CO<sub>2</sub> separation), gas drying (H<sub>2</sub>O separation) and stabilisation and separation of condensates and produced water, with the reinjection of H<sub>2</sub>S, CO<sub>2</sub> and H<sub>2</sub>O by using membranes (31, 33, 36).</p> <div data-bbox="860 1134 1266 1953" data-label="Diagram"> </div>		

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**Method and apparatus for separating a well stream**

The invention relates to a method of recovering hydrocarbons in a sub-surface reservoir, wherein a production flow is subjected to a separation process in the well hole.

To separate oil and water in a well hole is known, for example, from US 4296810. The separator used is built up of semi-permeable membranes. The separated water, produced water, is injected into a waste zone above or below the production zone.

US 4659343 makes known the separation of carbon dioxide from light hydrocarbons with the aid of a membrane arrangement. During the separation through the semipermeable membrane, a condensate emerges (hydrocarbons in liquid form) in contact with the membrane. These (liquified) liquid hydrocarbons are separated from the gases which do not pass through the membrane. This separation takes place by means of conventional membrane technology used in traditional processes within the processing industry.

Gravitation separation of hydrocarbons and water in a well hole is known, for example, from US 4766957. The produced water flows into a waste zone and the oil passes upward to the surface.

US 4805697 describes the reinjection of produced water, resulting from the separation of hydrocarbons and water in a centrifugal separator, of the dynamic or static type, regulated as a function of the hydrocarbon content in the produced water.

Hollow fibre separation (the hollow fibres are of a semipermeable membrane material) is discussed in US 5176725.

NO B 173426 describes the use of cyclone separators in the separation of oil and water in a well hole.

The processing of a production flow in a well hole gives rise  
5 to great advantages, especially by virtue of the fact that one does not need to lift, separate or remove the produced water.

The objective of the present invention is to provide, in the hole, a process which makes possible the supply of gas free  
10 of unwanted gases at the surface, with the possibility of reinjecting produced water and the separated, unwanted gases into a waste zone, so that one avoids cost-intensive lifting etc, of the unwanted parts of the production flow and avoids having to conduct these unwanted parts back into the reservoir  
15 through special reinjection/waste wells or dumping into the sea or the atmosphere.

According to the invention, it is proposed to carry out a cyclone separation of gas and liquid with a subsequent cyclone  
20 separation of condensate/oil from water at high pressure in the well hole, as well as a separation of the gas phase's unwanted gases,  $H_2S$ ,  $CO_2$  and  $H_2O$ , by using membranes under high pressure in the well hole.

25 The separated gases may to advantage be dissolved in a liquid, preferably sea water, prior to reinjection into a waste zone, a reinjection zone or to a recipient.

Such highly pressurised sea water in a well/reservoir can  
30 dissolve large quantities of gas. The reject from the membrane may therefore contain small amounts of gas together with  $H_2S$ ,  $CO_2$ , which it is not economical to separate further and which again may be dissolved in sea water through a chamber which mixes gas and sea water and dissolves the  
35 residual gases for further injection into a waste reservoir or to further dilution and emission to a recipient.

The invention relates also to an arrangement for use on the recovery of hydrocarbons in a sub-surface reservoir, comprising cyclone separators inside a well hole. The arrangement is characterised in that it comprises a cyclone separator for separating gas and liquid and a cyclone separator for separating condensate/oil from water at high pressure in a well hole, and a membrane arrangement for the separation of the gas phase's unwanted gases,  $H_2S$ ,  $CO_2$  and  $H_2O$ , at high pressure in a well hole. The cyclone separators and the membrane arrangement may to advantage be placed in a pipe string, which may be a permanent part of a production string or a free-standing part which can be lifted by known means.

The invention relates also to an arrangement of processing elements of a particularly weight and space-saving nature which may be used on an existing wellhead platform, where the arrangement/string is a part of the riser, or a separate pipe along one of the girders etc, or as an integrated part of a floating vessel/loading buoy.

Several cyclone separators and/or membrane arrangements may be connected in series relation.

One advantage that is achieved by means of the invention is the supply of a gas and a condensate as finished products ready to flow directly from the well to transport pipelines and consumers.

One avoids process platforms and investments running into billions and thus emissions of  $CO_2$  into the air, and consequently  $CO_2$  taxes. There is a reduction in requirements to be met by materials (after  $CO_2$  removal) in the well/seabed installation and the transport pipeline. It will be unnecessary to add glycol/methanol in the transport pipeline, and one avoids a methanol/glycol recovery plant or purification plant. Furthermore, one will avoid the formation of hydrates in the transport pipelines. The reinjection of

an uneconomical gas portion into the membrane reject may be permitted, as the gas does not pass into the atmosphere.

The invention shall now be described in detail with reference  
5 to the drawings where:

Fig. 1 is a schematic outline of a well hole with an arrangement according to the invention, with appurtenant pressure diagram;

10 Fig. 2 is a process diagram for the invention;

Fig. 3 illustrates a multi-step membrane arrangement;

Fig. 4 illustrates a cyclone separator for separating gas/condensate/water; and

Fig. 5 is a horizontal section along line A-A in Fig. 4

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The well hole 1 shown in outline in Fig. 1 passes through a waste zone 2 and a production zone 3. A production string 4 is located in the well hole and is sealed in the well hole 1 by means of suitable packers 5-8. A lower packer 8 and a  
20 lower intermediate packer 7 demarcate the production zone, whilst an upper intermediate packer 6 and an upper packer 5 demarcate the waste zone. A distribution valve 9 is provided above the lower intermediate packer 7, whilst a distribution valve 10 is located above the upper intermediate packer 6.

25

A plurality of cyclone generators 11 are located in the production string 1, between the lower packer 8 and the lower intermediate packer 7, whilst a plurality of membrane arrangements 12 are located in the production string 1,  
30 between the two intermediate packers 6 and 7.

Gas and liquid flow from the reservoir (production zone 3) to the annulus 13 and to the cyclone separators 11, as indicated by means of the arrows. Separated gas and liquid pass from  
35 the cyclone separators upward in the production string and the well hole respectively. The process will be explained in detail with reference to Fig. 2 and Figs. 3 to 5.

The production flow 3 passes from the gas/condensate reservoir 3 to the cyclone separators 11a. Gas passes as top reject to the distribution valve 9 and thence to the membrane arrangement 12 where unwanted gases  $H_2S$ ,  $CO_2$  and  $H_2O$  are separated, whilst dry, clean gas continues upward to the surface. The bottom reject from the cyclone separators, which is condensate and water in a mixture, flows to the cyclone separators 11b, whence condensate passes as top reject and produced water passes as bottom reject. The condensate is conducted to the surface. The separated, unwanted gases and produced water pass to the recipient 13 and/or to a pump 14 for reinjection into the waste zone 2. In the process diagram in Fig. 2, an alternative reinjection pump 15 has been drawn in a waste zone below the production zone. The pump 14 (and 15) is operated by a hydraulic medium, which may be sea water in the well hole which, in this case, is presumed to be an offshore well hole. The sea water may to advantage, also as shown, be used in a cooler 16 for the gas.

Figures 4 and 5 show an example of a cyclone separator unit which may be used on the implementation of the method according to the invention. Here, as in Fig. 1, the well hole is indicated by means of the reference numeral 1, and comprises a perforated wall 17. The production pipe, as in Fig. 1, is indicated by means of the reference numeral 4.

The cyclone separators 11a,b are located centrally in a pipe element 18. Therearound are located sectioned ducts 19, 20 and 21 for the separated gas, condensate 20 and produced water 21 respectively (Fig. 5). The inlet to the cyclone separator 1a, which is a gas/water separator, is indicated by means of the reference numeral 22 and is covered by a grill 23. The cyclone separator 11b has a top outlet 24 for separated gas and opens into the gas duct 19. The bottom outlet 25 of the cyclone separator 11a passes via a distribution section 26 to the cyclone separator 11b through pipeline 27 (Fig. 4). The cyclone separator 11b is a condensate/water separator. The

top reject, condensate, flows through the pipeline 28 to the condensate duct 20, whilst the bottom reject, produced water, flows to the duct 21 at 29.

5 In Fig. 4, yet another cyclone separator 11a is indicated (at the bottom in the figure), to show that several cyclone separator units, as described, may be provided one after the other in the pipe element or pipe string 18, in parallel operation, as in Fig. 2.

10

Fig. 3 shows an example of a multi-step membrane arrangement which may be used on the implementation of the invention, i.e., for the part which relates to membrane separation of unwanted gases, disclosed herein as  $H_2S$ ,  $CO_2$  and  $H_2O$ .

15

Untreated, separated gas from the cyclone separators (11a in Fig. 4) flows through the pipeline 30 to a first membrane 31. Thence the purified gas flows through the pipeline 32 to a second membrane 33 for further purification/separation. Clean  
20 gas is withdrawn through the pipeline 34 and passes to the pipeline 35, which conducts purified gas from a third membrane 36. This membrane separates gas from the  $CO_2$ ,  $H_2S$ ,  $H_2O$  enriched gas from the membrane 31. The enriched gas portion including unwanted gases is conducted as shown from the first  
25 membrane 31 to the third membrane 36 through a pipeline 37. Clean gas passes from the third membrane 36 to the pipeline 35 and  $H_2S$ ,  $CO_2$ ,  $H_2O$  rich gas passes to the pipeline 38, to which separated gas from the second membrane 33 is also conducted through the pipeline 39.

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P a t e n t   c l a i m s

1.

A method for the recovery of hydrocarbons in a sub-surface  
5 reservoir, wherein a production flow is subjected to a  
separation process in the well hole, characterised in that a  
cyclone separation of gas and water is carried out with a  
subsequent cyclone separation of condensate/oil from water at  
high pressure in the well hole, and a separation of the gas  
10 phase's unwanted gases,  $H_2S$ ,  $CO_2$ ,  $H_2O$ , by using membranes under  
high pressure in the well hole.

2.

A method according to Claim 1, characterised in that the  
15 separated unwanted gases are reinjected into a waste zone or  
a reinjection zone.

3.

A method according to Claim 2, characterised in that the  
20 separated unwanted gases are dissolved in a liquid, preferably  
sea water, prior to reinjection.

4.

An arrangement for use in the recovery of hydrocarbons in a  
25 sub-surface reservoir, comprising cyclone separators in a well  
hole, characterised by a cyclone separator for separating gas  
and liquid and a cyclone separator for separating  
condensate/oil from water at high pressure in the well hole,  
and a membrane arrangement for separating the gas phase's  
30 unwanted gases,  $H_2S$ ,  $CO_2$  and  $H_2O$ , at high pressure in the well  
hole.

5.

An arrangement according to Claim 4, characterised in that it  
35 is provided in the form of a string in the well, in the  
reservoir and seabed or between the seabed installation and  
the platform/ floater/ vessel/ buoy, where the string may be

drawn up by means of a wireline, coiled tube or as a part of the production pipe.

6.

- 5 An arrangement according to Claim 4, characterised in that it is provided in the form of a string in a dummy well, a casing from 3-30 inches, deposited as a well element on the seabed, and as a part of the seabed installation.

10 7.

An arrangement according to Claim 4, characterised in that it is provided in the form of a string in a riser or similar on a platform, in a loading buoy or similar of minimum weight and bulk.

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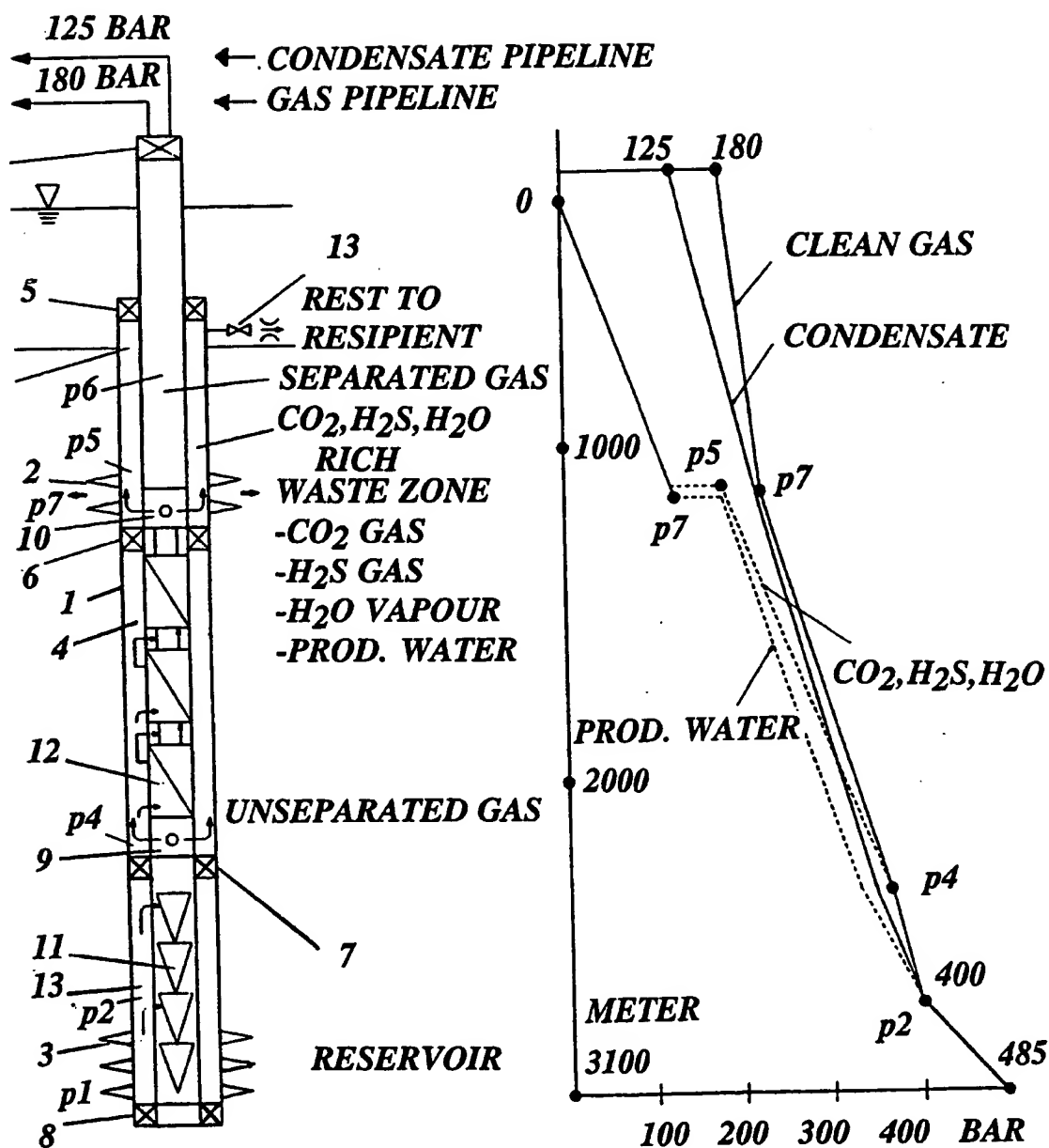
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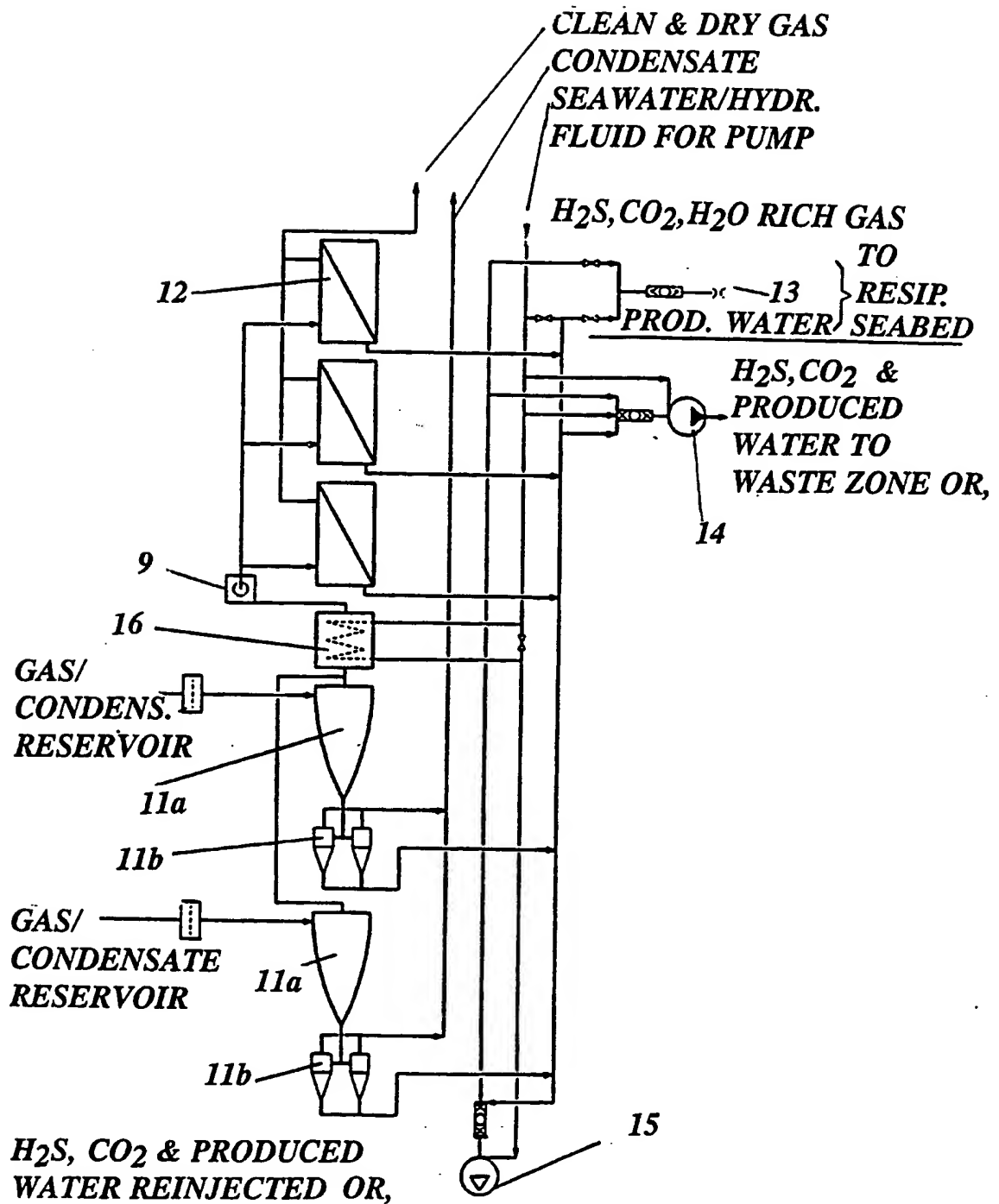
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FIG. 1



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FIG. 2



3/4

FIG. 3

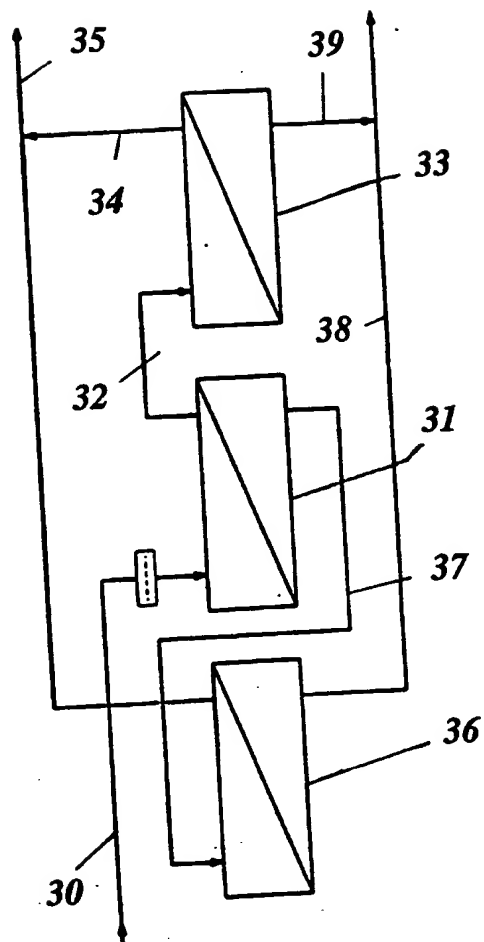
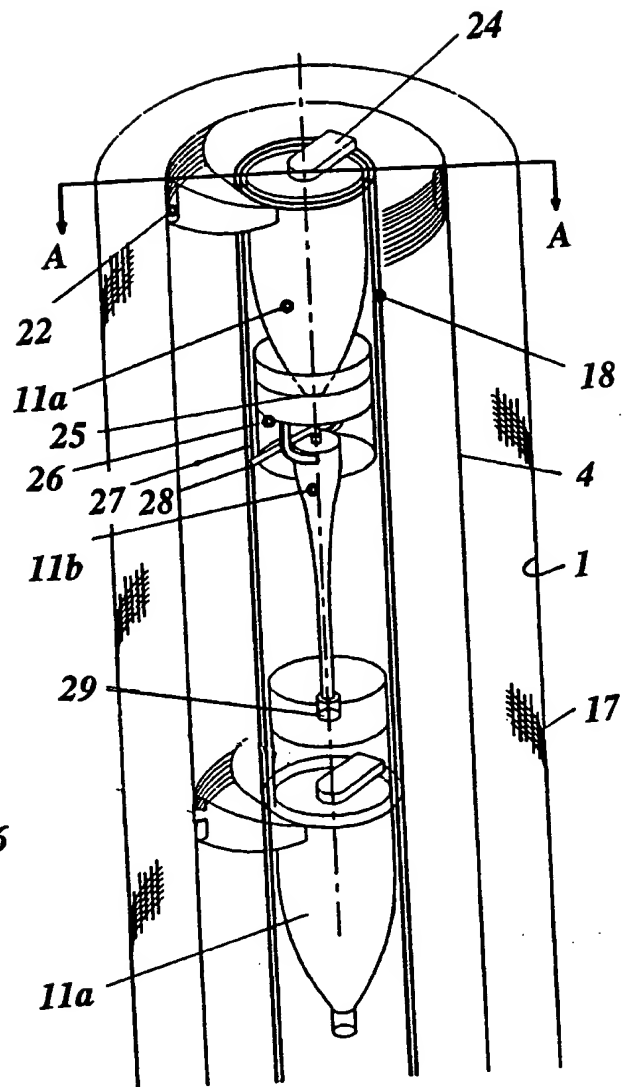
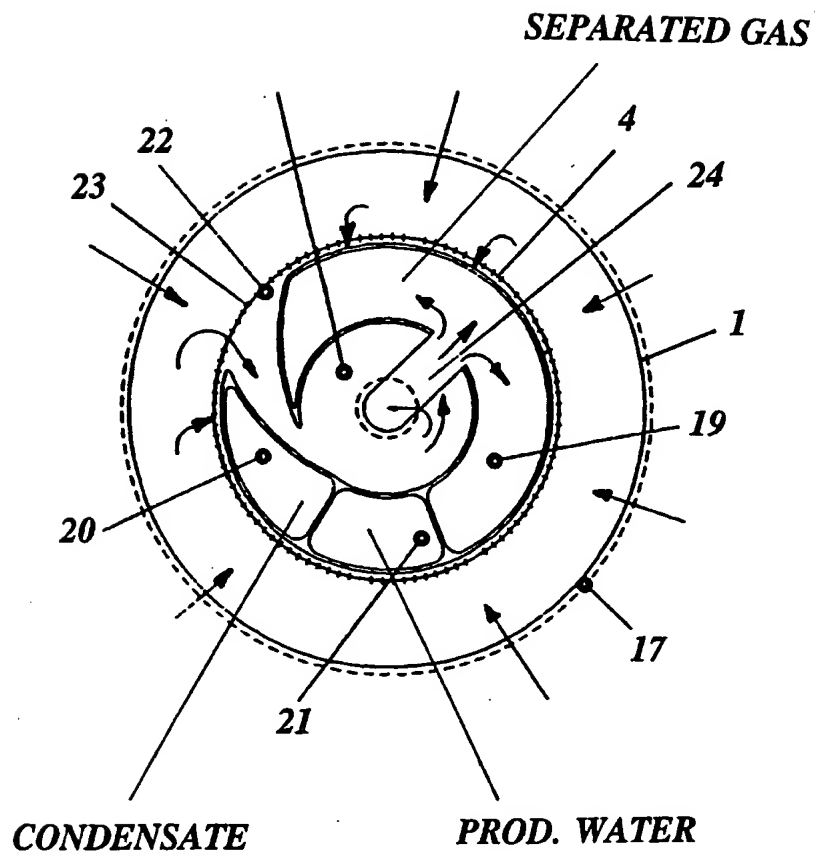


FIG. 4



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FIG. 5



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 94/00159

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: E21B 43/38

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4805697 (C. FOUILLOUT ET AL), 21 February 1989 (21.02.89), the whole document --	1-7
Y	US, A, 4659343 (R.M. KELLY), 21 April 1987 (21.04.87), the whole document --	1-7
A	GB, A, 2194572 (SOCIETE NATIONALE ELF AQUITAINE (PRODUCTION)), 9 March 1988 (09.03.88) --	1-7
A	EP, A1, 0022357 (PRICE, ERNEST H.), 14 January 1981 (14.01.81) --	1-7

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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PCT/NO 94/00159

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4296810 (E.H. PRICE), 27 October 1981 (27.10.81)  -- -----	1-7



# INTERNATIONAL SEARCH REPORT

Information on patent family members

26/11/94

International application No.

PCT/NO 94/00159

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4805697	21/02/89	FR-A,B- 2603330 GB-A,B- 2194575	04/03/88 09/03/88
US-A- 4659343	21/04/87	AU-B- 599331 AU-A- 6217686 CA-A- 1305074 DE-A,T- 3688724 EP-A,B- 0214641	19/07/90 12/03/87 14/07/92 26/08/93 18/03/87
GB-A- 2194572	09/03/88	FR-A,B- 2603205 US-A- 4793408 FR-A,B- 2603206	04/03/88 27/12/88 04/03/88
EP-A1- 0022357	14/01/81	CA-A- 1134259 JP-C- 1267582 JP-A- 56038102 JP-B- 59045069 US-A- 4241787	26/10/82 10/06/85 13/04/81 02/11/84 30/12/80
US-A- 4296810	27/10/81	NONE	

1/1 WPAT - (C) Derwent

AN - 1990-064014 [09]

XA - C1990-028005

TI - Gas sepn. for mixed gas - by applying revolving force to mixed gas,  
putting gas into supersonic expansion nozzle

DC - J01

PA - (MITO ) MITSUBISHI HEAVY IND CO LTD

NP - 1

NC - 1

PN - JP02017921 A 19900122 DW1990-09 3p \*

AP: 1988JP-0165849 19880705

PR - 1988JP-0165849 19880705

IC - B01D-053/24

AB - JP02017921 A

Gas separation comprises giving a revolving force to the mixed gas and  
entering the gas into a supersonic expansion nozzle to condense or  
freeze a part of a component of the gas.

- USE - For air sepn. (0/4)

MC - CPI: J01-A03 J01-E03

UP - 1990-09